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(54) System for fastening a hollow extruded blade for an axial-flow fan to the inserted shank of the blade.

(57) A hollow extruded axial flow fan blade is described which comprises two internal longitudinal reinforcing elements (ribs) (5) perpendicular to the blade profile (3) and in which are inserted through bolts (4) for fastening the blade to the round supporting bar inserted longitudinally in said blade, said bolts completely internal to said blade being parallel to the plane of revolution of the blade and passing diametrically and perpendicularly through the round supporting bar (2).

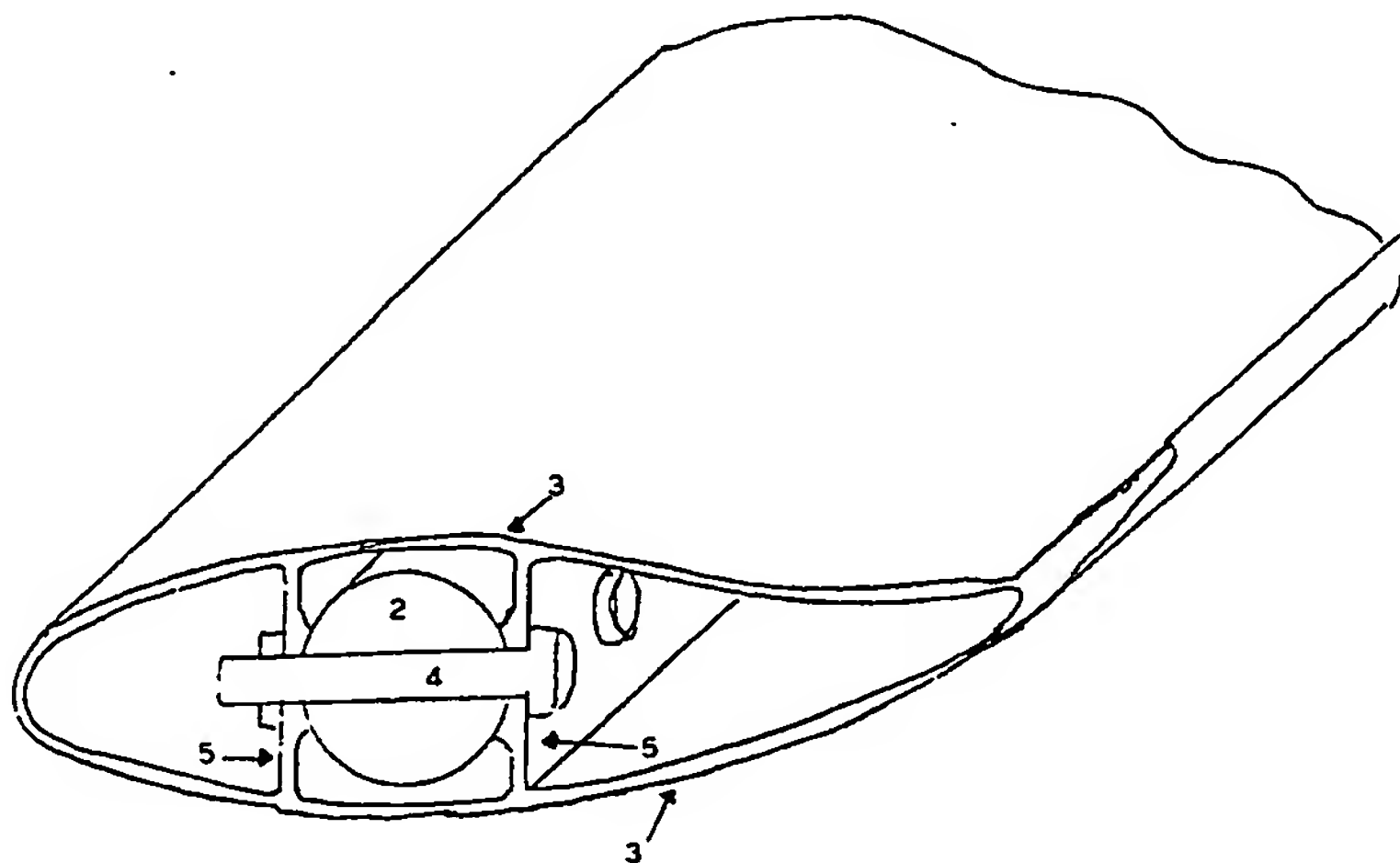


FIG. 2

EP 0 447 000 A1

The present invention relates to a system for fastening a hollow extruded blade for an axial-flow fan to the round supporting bar inserted in said blade longitudinally. The round bar or 'blade shank' is fastened by the inner end to the hub of the fan. Normally the round bar is fastened to the blade by bolts passing completely through the blade perpendicularly to the profile thereof.

5 When necessary the system can be reinforced in the involved zone by interposing appropriate elements, usually plates, placed on the front and/or rear face of the blade.

There are thus the two basic arrangements illustrated in FIG. 1. The first fastening method proposed by the present invention is based on the use of bolts 4 arranged parallel to the plane of rotation of the blade and completely internal to it and a corresponding internal structure of the blade comprising longitudinal
10 reinforcements (ribs) 5 perpendicular to the profile in which the bolts are inserted. The bolts are at least two in number and pass diametrically and perpendicularly through the round bar or insert 2.

The arrangement is shown in FIG. 2.

The new proposed fastening method shows numerous advantages compared with the conventional methods.

15 The principal ones are explained as follows:

(a) Better aerodynamics of the blade:

in the 'c' configuration there are no parts protruding from the blade profile with the resulting obvious aerodynamic advantages, which can be summarized essentially in:

- 20 - better efficiency of the blade and hence of the fan,
- less turbulence and consequently:
- less noise,
- lower level of nonstationary loads;

(b) Better structural strength of the insert:

25 The forces acting on the insert are the following:

1) Operating fan

It has been shown experimentally that a large percentage of the bending moment M_f , even up to 100%,
30 has an alternating load with frequency 1 per revolution and n per revolution, where n is the number of blades, thus subjecting the material to fatigue, the effect of which is more critical than that of the static loads [see FIG. 3 where (1) indicates the fan hub, (2) indicates the blade shaft or insert and (3) indicates the two walls of the blade];

35 2) Starting fan [see FIG. 4]

Centrifugal force F_c and twisting moment M' can be considered static loads, being variable but with a frequency equal to the number of starts, hence extremely low.

Considering that:

- 40 - M' is normally much less than M_f
- M' has (contrary to M_f) practically no effect from the point of view of fatigue damage,
- F_c is a static load (applied a number of times equal to the number of starts),

the critical load for the root of the blade and the insert is M_f considered as an alternating load with frequency equal to n per revolution.

45 It acts perpendicularly to the plane of the blade.

Consequently the critical sections are:

a) for the insert:

- 50 - the zone of greatest load and least structural strength, i.e. the section at the bolt hole nearest the hub;

b) for the blade.

- the zone where the load has not yet been shifted from the blade to the insert, approximately at the end of said insert.

55 The levels of stress in the critical section of the insert will now be analyzed, comparing configurations 'a' and 'b' with configuration 'c'.

Critical section

Configurations 'a', 'b' [see FIG. 5]; Configuration 'c' [see FIG. 6].

Resisting moment of the section related to point A in the first case W, in the second case W':

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$$W = \left(\frac{\pi D^3}{32} - \frac{D^2 \cdot x d}{6} \right) \quad W' = \left(\frac{\pi D^3}{32} - \frac{D \cdot d^2}{6} \right)$$

10

Maximum stress at A:

$$\delta = Mf/W \quad \delta' = Mf/W'$$

15

Since $W' > W$ it follows that the maximum nominal bending stress in configuration 'c' is less than in configurations 'a' and 'b'. To give an idea of the percentage of improvement an example is shown using sufficiently typical and representative data:

20

$$\begin{aligned} D &= 75\text{mm} \\ d &= 12\text{mm} \\ Mf &= 100000\text{kgmm} \end{aligned}$$

25

Configurations 'a', 'b':

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$$\begin{aligned} W &= 30146\text{mm}^3 \\ \delta &= 3.31\text{kg/mm}^2 \end{aligned}$$

Configuration 'c':

35

$$\begin{aligned} W' &= 39.596\text{mm}^3 \\ \delta' &= 2.52\text{kg/mm}^2 \end{aligned}$$

40

The stress in configuration 'c' is 24% less than the stress in configurations 'a' and 'b'.

c) Minimal effect of the force concentration factor due either to the presence of the hole or to processing defects at said hole in the insert.

Due to the presence of the hole and/or to processing defects at said hole the concentration factor applies to the most stressed zone of the hole edges. The advantage of configuration 'c' compared with 'a' and 'b' is thus clear.

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In fact, considering the critical fatigue load, i.e. the bending moment Mf, alternated with frequency n x revolution, in configuration 'c' the edge of the hole is at a distance d/2 from the neutral axis while in configurations 'a' and 'b' it is at a distance D/2.

It follows that in configuration 'c' the nominal stress to which the concentration factor applies is equal to d/D with respect to the other configurations.

50

Obviously, for the same concentration factor, the final resulting stress is in the same advantageous relationship for configuration 'c'.

Using as an example the above case and assuming a concentration factor of 3 we have:

55

Configurations 'a' and 'b'				Configuration 'c'	
	Mf	100000	kgmm	100000	kgmm
5	I	1130493	mm ⁴	1541568	mm ⁴
	Y	37.5	mm	6	mm
	k	3		3	
10	$\delta = Mfxy/I$	9.95	kg/mm ²	1.16	kg/mm ²

It can be seen that the beneficial effect is considerable.

15 In the starting stage of the fan the effect is obviously opposite, i.e. the stresses in configuration 'c' are higher than in configurations 'a' and 'b', but the effect is negligible because these loads are applied only a few times.

Summarizing and schematizing the example given in order by size, if the fan in question had 4 blades and rotated at 150 revolutions per minute for 5 years with one start per day and assuming for the
20 sake of simplicity that the moment upon starting is Mf we have:

Configuration 'a' and 'b'			Configuration 'c'	
25	Stresses/cycles	9.95/1.57 10 ⁹	2.43/1.57 10 ⁹	
	in zone A	1.16/1825	0/1825	
	Stresses/cycles	2.43/1825	9.95/1825	
30	in zone B	0/1.57 10 ⁹	1.16/1.57 10 ⁹	

The advantage of configuration 'c' is evident.

d) There are no holes on the outside of the profile, which is more stressed, and as a result there is less
35 possibility of formation of cracks due to fatigue. Indeed, the holes in configuration 'c' are near the neutral axis of the profile where stresses are extremely low. From this point of view, as concerns the profile, configuration 'c' is equivalent to configuration 'b' in which the reinforcements also have the function of preventing fatigue damage originating at the holes in the outside of the profile. In this case also, however, configuration 'c' displays a clear advantage in terms of cost. If for particular applications it
40 should be necessary in configuration 'c' to reinforce the root zone in order to increase safety margins, it would be possible to apply strengthening elements similarly to configuration 'b'.

Assembling the blades in accordance with the invention requires the use of two or more fastening bolts to be screwed inside the hollow structure of the blade. This operation requires special tools for screwing. In case of large blades (see FIG. 8) made up of two or three longitudinal sections welded together upon
45 assembly, the bolts are tightened to fasten the central section and then the side section (or sections) is (are) assembled and welded.

In another embodiment of the present invention the round supporting bar is fastened to the blade through an intermediate fastening element which is fixed on the rod by bolts parallel to the plane of revolution of the blade, said intermediate fastening element having external profile suitable for the internal
50 hollow structure of the blade.

The fastening of the intermediate element to the blade can be carried out by riveting or bolting or other conventional means.

Claims

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1. Hollow extruded axial flow fan blade comprising two internal longitudinal reinforcing elements (ribs) (5) perpendicular to the blade profile (3) and in which are inserted through bolts (4) for fastening the blade to the round supporting bar inserted longitudinally in said blade, said bolts completely internal to said

blade being parallel to the plane of revolution of the blade and passing diametrally and perpendicularly through the round supporting bar (2).

2. Axial flow fan blade according to claim 1, wherein there are at least two fastening bolts (4).

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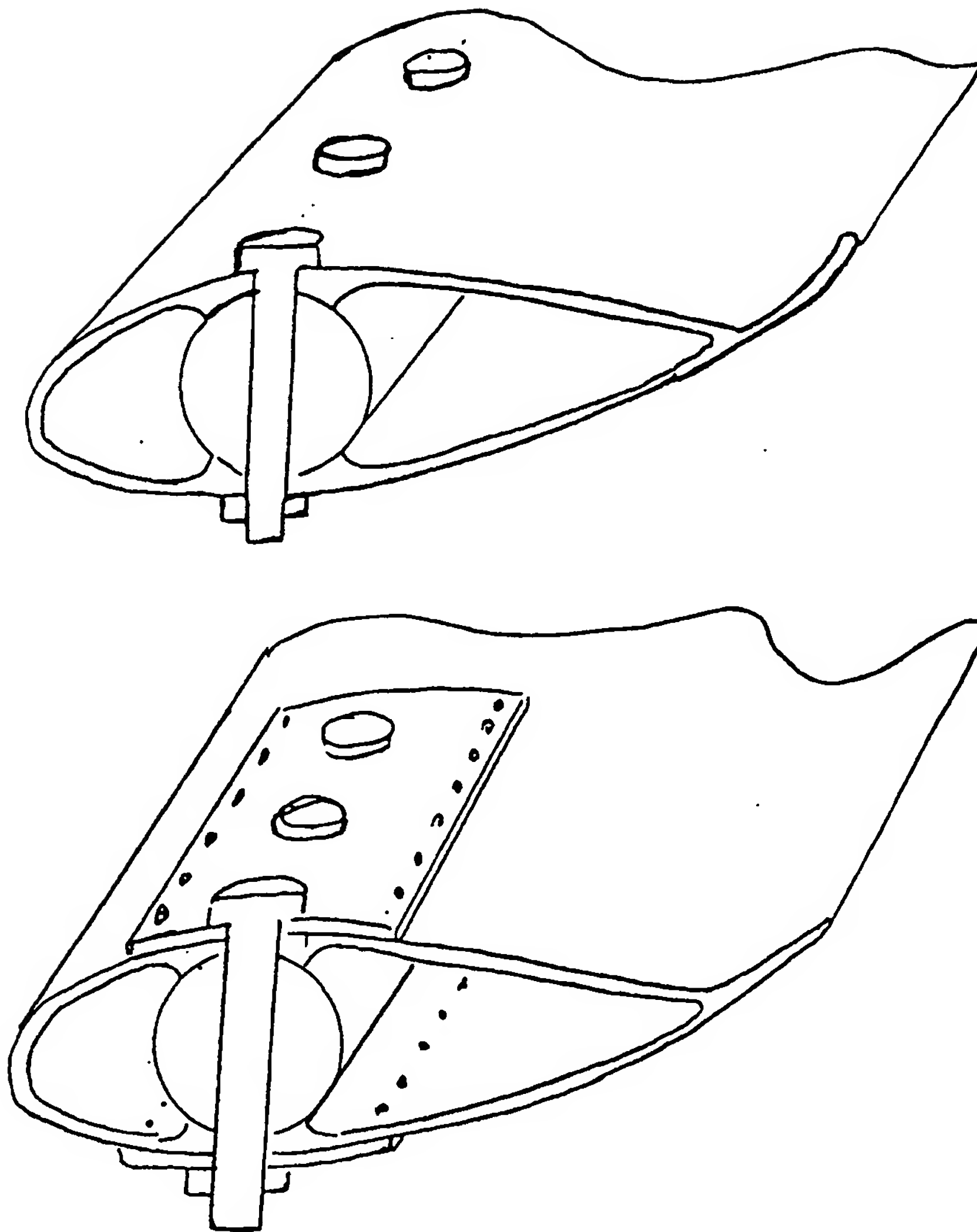


FIG.1

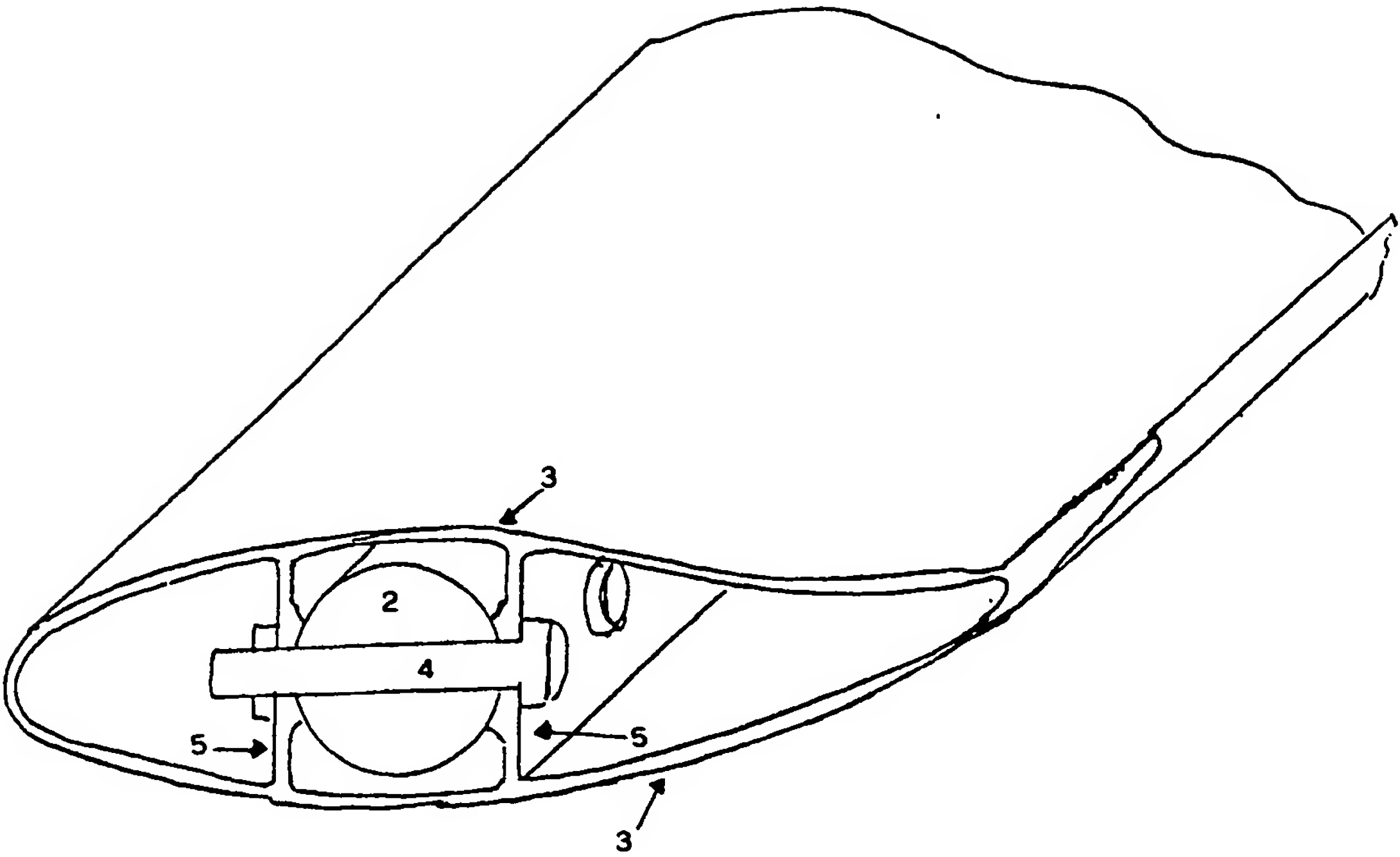


FIG.2

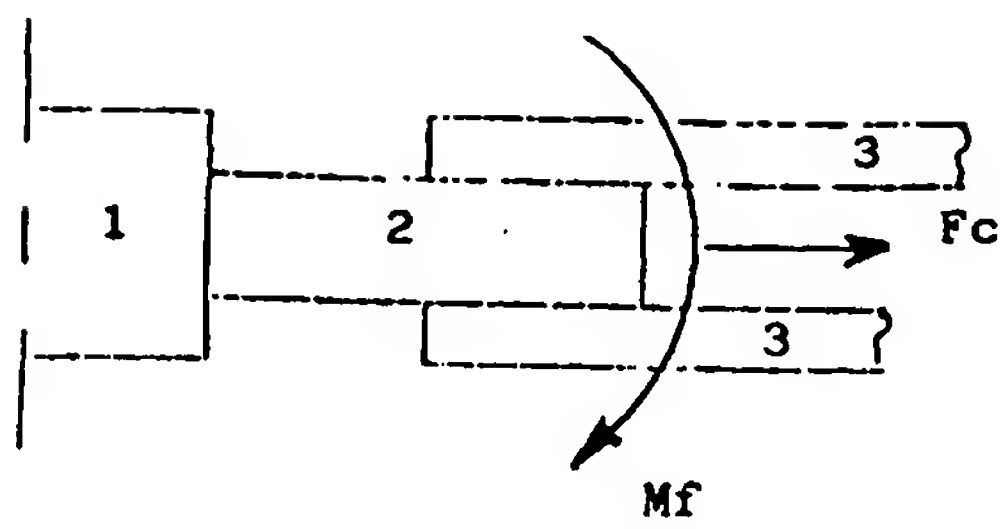


FIG. 3

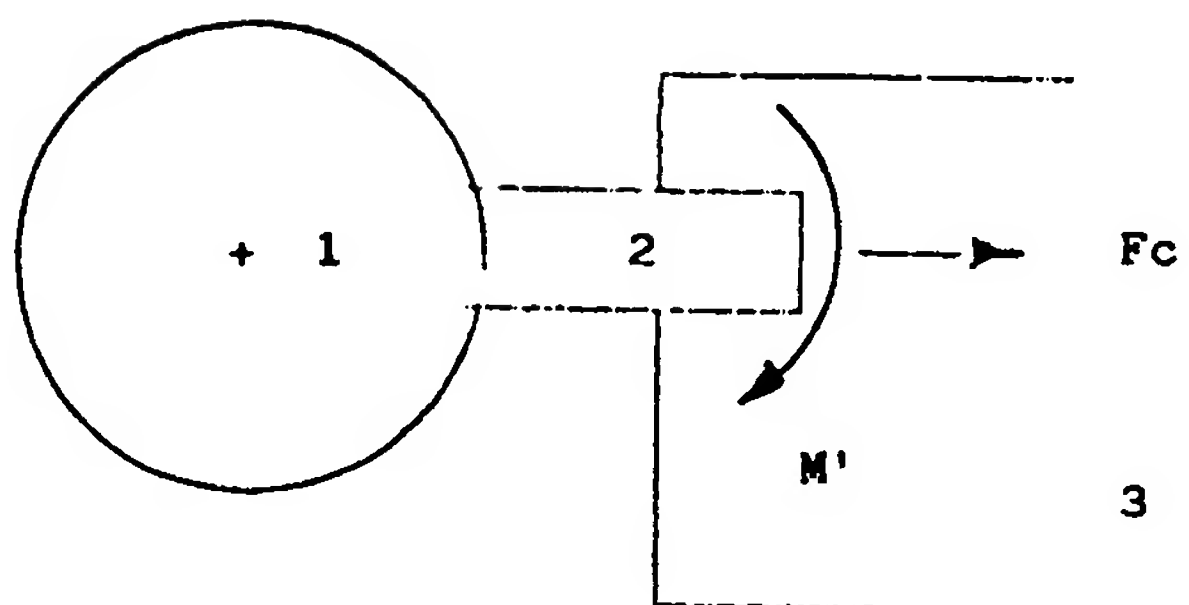
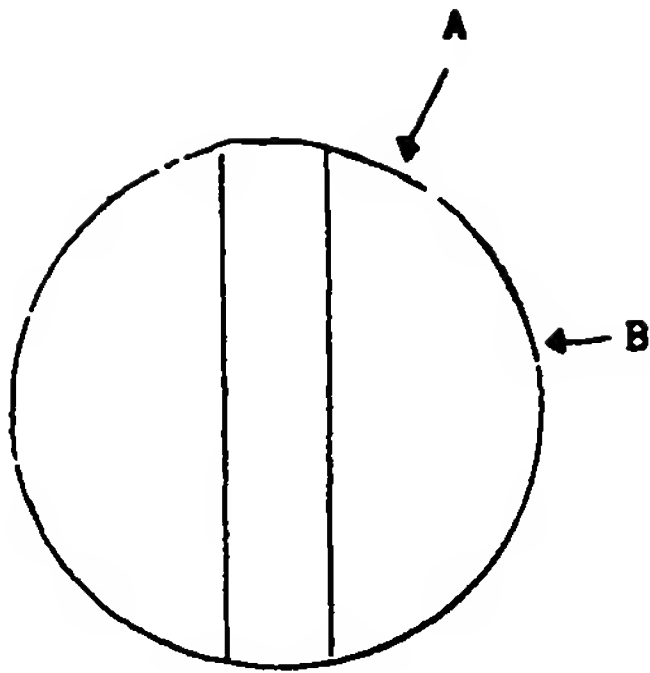
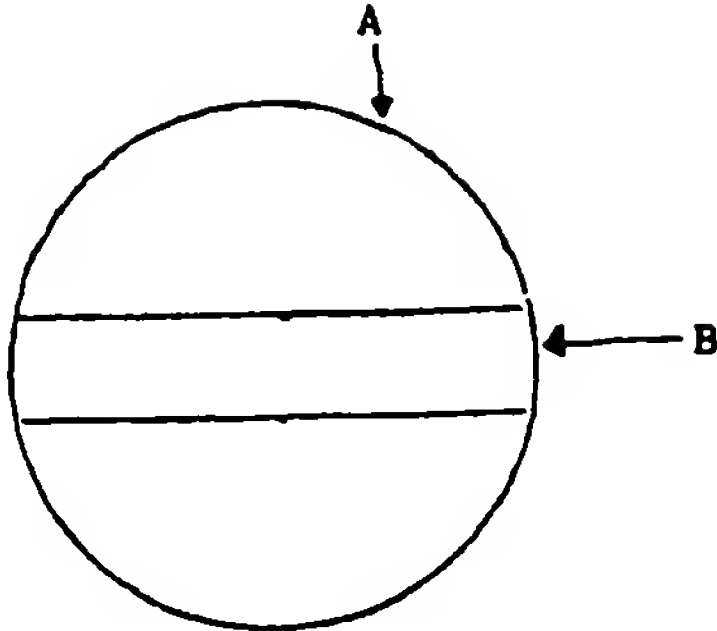


FIG. 4



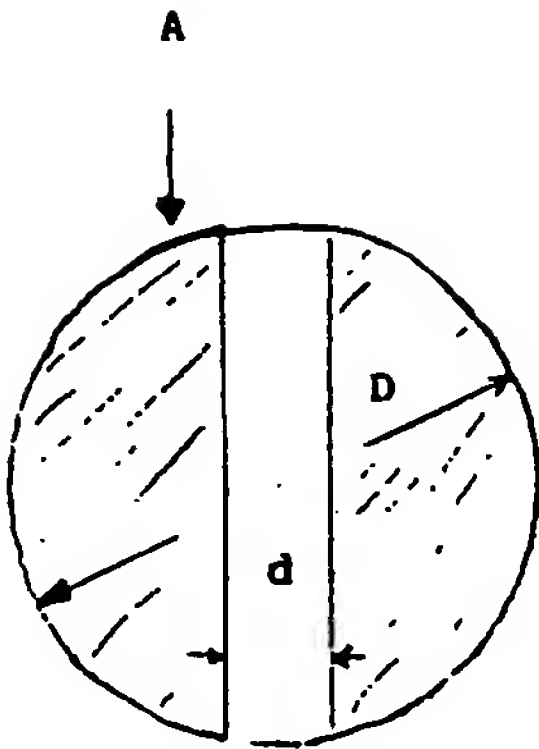
"a" and "b"

FIG.5

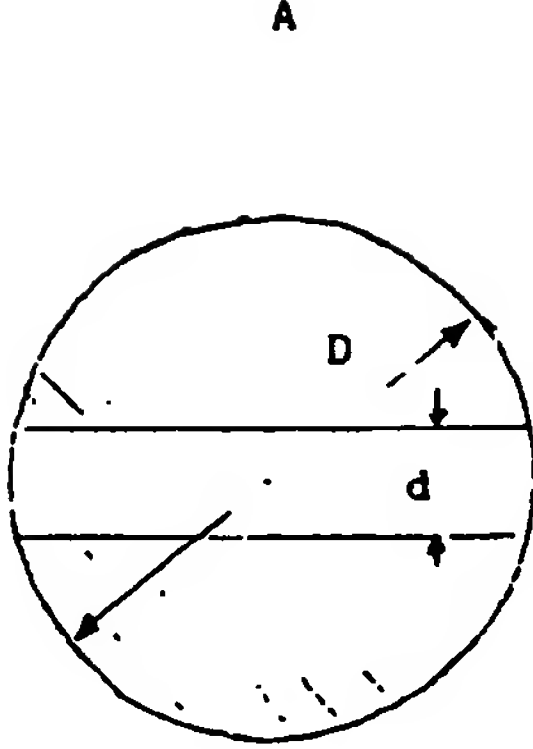


"c"

FIG.7



"a" and "b"



"c"

FIG.6

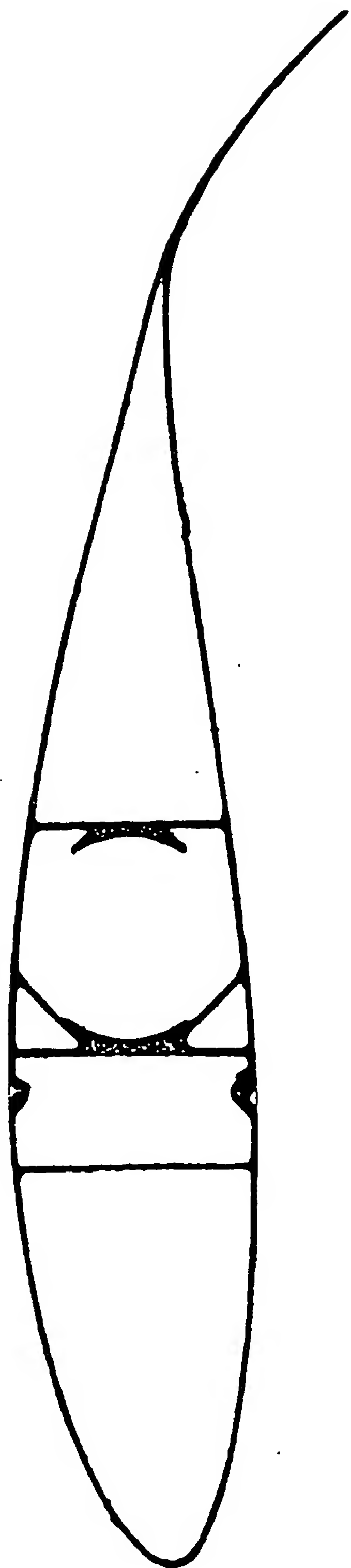


FIG. 8



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EUROPEAN SEARCH REPORT

Application Number

EP 91 20 0537

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	EP-A-0 258 926 (STRIJENSE KUSTSTOF TECHN. BV) * Column 4, lines 17-24 * - - - -	1	F 03 D 1/06
A	CA-A-1 168 503 (COWL) * Page 3, line 28 - page 4, line 10; page 4, line 26 - page 5, line 13 * - - - -	1	
A	EP-A-0 095 807 (MULTINORM B.V.) * Page 7, lines 10-22; figures 4,5 * - - - - -	1,2	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			F 03 D
The present search report has been drawn up for all claims			
Place of search		Date of completion of search	Examiner
The Hague		24 May 91	DE WINTER P.E.F.
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